Innovative Coastal-Ocean Observing Network (ICON) Renewal

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Document Number: N0001402WR20086
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LONG-TERM GOALS

The Innovative Coastal-Ocean Observing Network (ICON) is a partnership of government, academic, and industrial entities funded by the National Ocean Partnership Program (NOPP). Its goal is to bring together modern measurement technologies, to develop new technologies, and to integrate them within a data assimilating coastal ocean circulation model.

OBJECTIVES

The objectives of the project are to evaluate the several real-time observing systems as components of future coastal monitoring networks as well as sources for data-assimilating numerical models.

APPROACH

The approach taken in this project was to build on existing partnerships and observing systems around the Monterey Bay region. The major components of the observing network included 1) surface current maps from shore-based high frequency (HF) radar installations, 2) subsurface currents, temperature, salinity, and bio-optical properties plus surface meteorological properties from several deep-ocean moorings, 3) sea surface temperature and color from satellites, and 4) along-track temperature and temperature variances from two acoustic tomography slices through the region. These data sets each involved real-time data telemetry. They were also used as either validation or assimilation sources for a nested, primitive equation numerical model. The ICON P.I. group and their respective areas of research are listed in Table 1.

Table 1. ICON Partner Institutions and Primary Responsibilities

Naval Postgraduate School (NPS; J. Paduan, C. Collins, L. Rosenfeld, S. Ramp, C.-S. Chiu)	Project management; Moored, HF Radar, Ship, and Acoustic Tomography Observations
Univ. of Michigan (J. Vesecky*)	HF Radar Construction
Calif. State Univ. Monterey Bay (D. Fernandez)	HF Radar Observations
Univ. of Southern Mississippi (I. Shulman)	Circulation Modeling and Data Assimilation
Naval Research Laboratory (J. Kindle)	Regional Modeling; Bio-Physical Modeling
HOBI Labs, Watsonville, CA (R. Maffione)	Moored Optics Sensors, Bio-Physical Modeling
Monterey Bay Aquarium Res. Inst. (F. Chavez)	Mooring Construction, Bio-Physical Modeling
Codar Ocean Sensors, Los Altos, CA (D. Barrick)	HF Radar Maintenance and Algorithms

*now at: University of California Santa Cruz

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Innovative Coastal-Ocean Observing Network (ICON) Renewal**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Oceanography, Code OC/Pd, Naval Postgraduate School,,Monterey,,CA, 93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Innovative Coastal-Ocean Observing Network (ICON) is a partnership of government, academic, and industrial entities funded by the National Ocean Partnership Program (NOPP). Its goal is to bring together modern measurement technologies, to develop new technologies, and to integrate them within a data assimilating coastal ocean circulation model.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

WORK COMPLETED

This project utilized two types of HF radar systems: the commercially available CODAR/SeaSonde unit and the Mutli-Frequency Coastal Radar (MCR). The latter is under development by partner J. Vesecky. The MCR is unique in its ability to transmit and receive backscatter signals on four frequencies simultaneously within the HF band. In principle, this provides for the possibility to measure velocity shear very near the ocean surface (within 1-2 m). MCR improvements were incorporated in this project with the construction of the third experimental system (SN3), including: 1) a capability for recording engineering housekeeping data, 2) a new VSWR protection circuit, 3) improved temperature stability of the receiver's gain control function, and 4) modifications to the transmitter modulator to improve linearity and reduce distortion. With the deployment of the SN3 MCR system at Granite Canyon south of Monterey Bay and the deployment of a new SeaSonde unit on Pt Sur further south, the surface velocity mapping capability was extended beyond Monterey Bay to include the upwelling center offshore Pt Sur. Extensive comparisons of radial current data from co-located SeaSonde and MCR units at Santa Cruz and Moss Landing in Monterey Bay were conducted by the HF radar team and presented at the 2nd International Radiowave Oceanography Workshop (ROW-2) in Landeda, France in April. Data from the independent HF radar systems agree well with RMS differences on the order 10 cm/sec, which is comparable to the radar-to-mooring agreement found by other investigators.

Data from the HF Radar network was collected and processed along with bio-physical data from four deep-ocean mooring sites and one, shorter-term, meteorological turbulence measurement site. In addition, acoustic data collected at the SOSUS array listening station offshore Pt Sur. was processed for travel time variations from two sources on Davidson Seamount and Pioneer Seamount to the West and North, respectively. Revisions to the forward-problem ray tracing between Davidson Seamount and Pt Sur were completed within the M.S. thesis work of D. Neander along with initial computations of the tomographic inverse.

RESULTS

Publication efforts are ongoing, but a number of results have been obtained and promulgated with regard to surface velocity maps from HF radar and their use with nested, data assimilating circulation models. Some of these results from the past year are highlighted here beginning with the description of the primary mode of variability in both the HF radar-derived currents and the wind-forced circulation model.

Surface current output from the nested, high-resolution circulation model run by I. Shulman (USM) was subsampled at the locations of the HF radar data within Monterey Bay for the purpose of computing comparable Empirical Orthogonal Function (EOF) representations of the velocity variability. In this case, both observed and modeled surface currents are dominated by along-coast flow across the mouth of Monterey Bay. Very similar patterns emerged in the data and model results for the most dominant mode (Figure 1). In both cases, that mode accounted for, approximately, 50% of the variance, while the second mode dropped to about 15% of the variance in the year-long sub-tidal-period velocity records.

In the Monterey Bay region, the primary velocity variance is related to the dominant alongshore wind variations, which flip between upwelling favorable and downwelling favorable during most of the year. The temporal amplitude of the HF radar-derived first velocity mode is highly correlated with this alongshore wind component (Figure 2). A similar correlation (not shown) can be demonstrated for the wind-forced model results prior to the use of data assimilation to incorporate HF radar measurements.

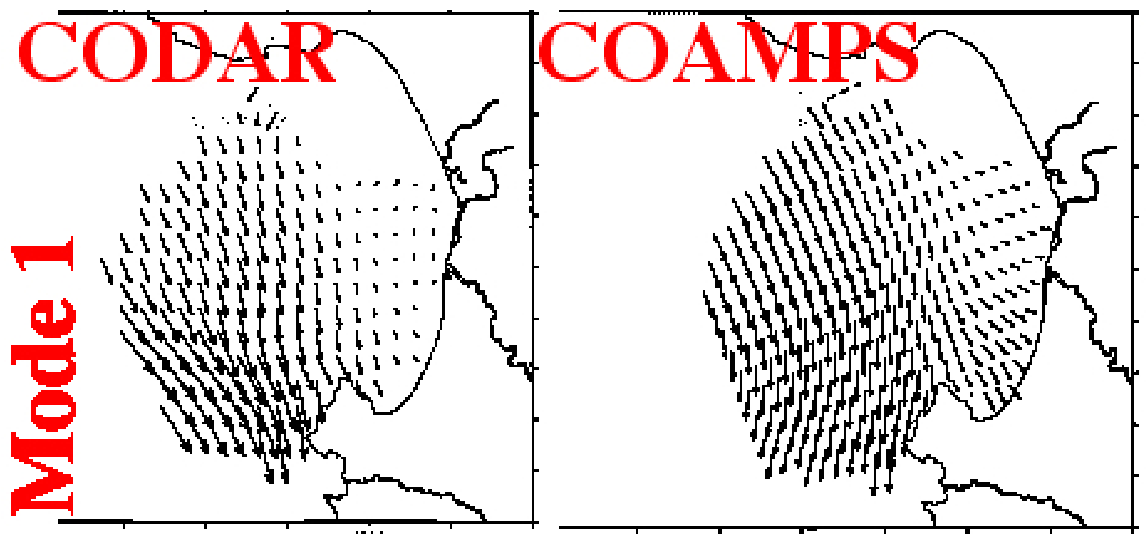

Figure 1. First spatial velocity mode for 1999 over the domain of the Monterey Bay HF radar coverage for the radar-based observations (CODAR) and for numerical model runs using high resolution (9 km; COAMPS) wind product. Note: low resolution (100 km; NOGAPS) forcing produced a similar first-mode pattern but different patterns at higher modes. Also note that, for scale, it is 40 km across the mouth of Monterey Bay.

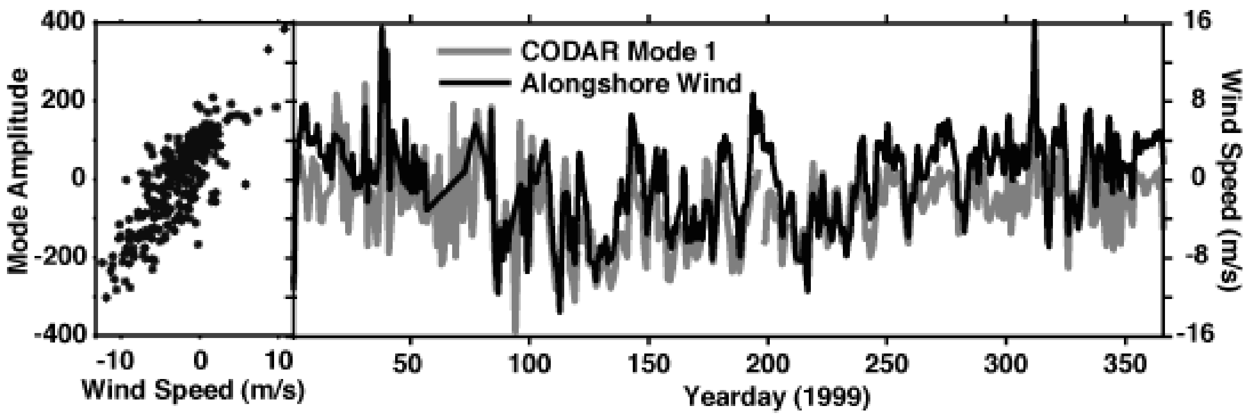

Figure 2. Alongshore component of wind at the M1 mooring near the center of Monterey Bay and the mode 1 amplitude for the radar-derived (CODAR) surface velocity fields as a scatter plot (left panel) and versus time (right panel).

The high degree of “success” achieved by the model with regard to the energetic, wind-driven surface current reversals did not translate into high skill with regard to the positioning of mesoscale fronts and eddies within the model domain. An important result of the model-to-mooring data comparisons undertaken is the fact that the nested, wind-forced circulation model may produce realistic features that are imprecisely located, which led to deceptively low skill scores with single-point comparisons.

When, instead, model currents throughout the domain were correlated with observed currents, high correlation results were obtained offset in space from the mooring location by just a few kilometers (Figure 3).

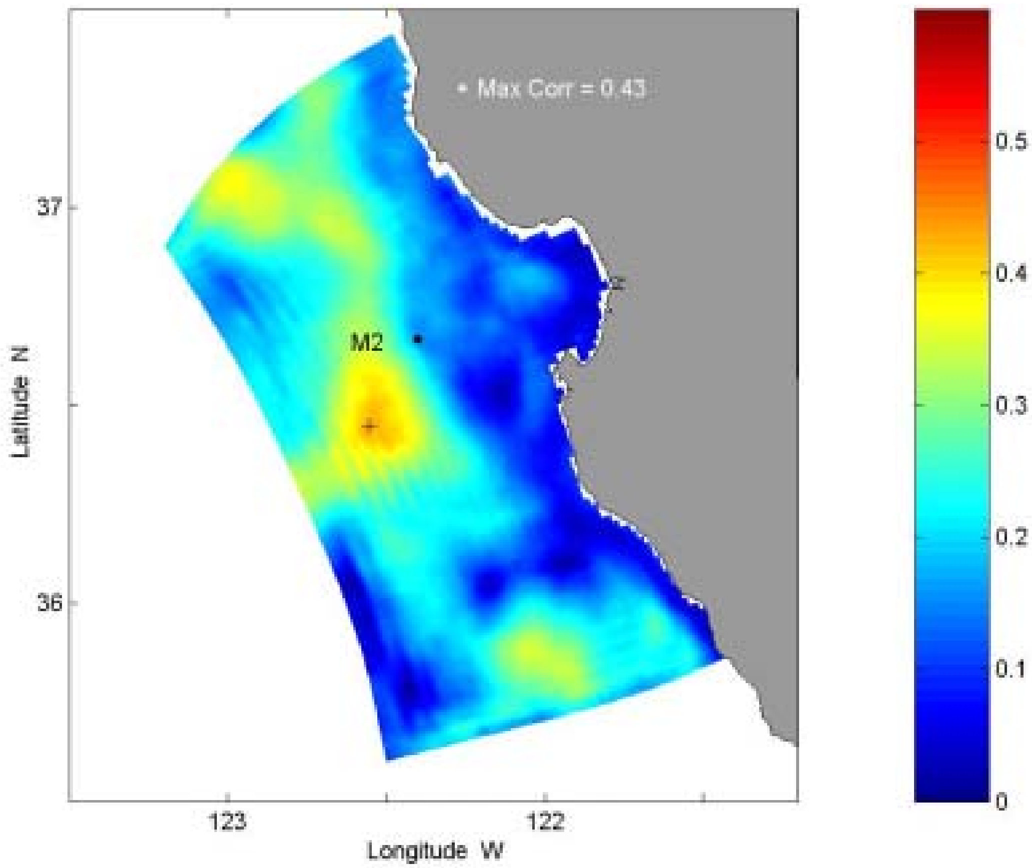

Figure 3. Magnitude of the complex surface velocity correlation for 1999 between ICON model output and observed currents at the M2 mooring site outside Monterey Bay. Values at the mooring location are low (~0.10), but there is a much higher peak value (0.43) about 20 km to the southwest.

The coastal modeling and observation results from ICON strongly suggest a role for data assimilation in the improvement of model nowcasts and forecasts. The observed larger scales are included in the model simulations and smaller scales are represented but offset in space. Preliminary results are available from work to use surface current maps from the HF radar network as a data assimilation source for the ICON model. In this highly complex domain where the offshore boundary reaches depths exceeding 3000 m and the interior includes the Monterey Bay and the topography of the Monterey Submarine Canyon, it is not expected that a significant correlation exists between surface currents and the state variables throughout the model domain. As an alternative to the development of such a 3-D data (and error) covariance matrix, we have investigated the “effective depth” achieved when observed currents are assimilated only into the surface, or near-surface, model level(s). At the heart of the surface assimilation technique is a truncated Kalman filter (PSAS) that utilizes observed data-data horizontal covariance scales computed monthly from the historical HF radar data set. Those scales have small seasonal variations, but mostly show alongshore (cross shore) decorrelation scales around 12 km (8 km).

The results of ocean current assimilation into the mixed layer levels of the ICON model provide encouragement that these data may improve open-coast circulation models down to depths of around 100 m (Figure 4). Work is ongoing to document the physical mechanisms by which favorable adjustments are made to the model currents below the level of direct assimilation. Presumably, this occurs due to divergences in the correction field, which shows the utility of 2-D velocity maps available only from HF radar systems.

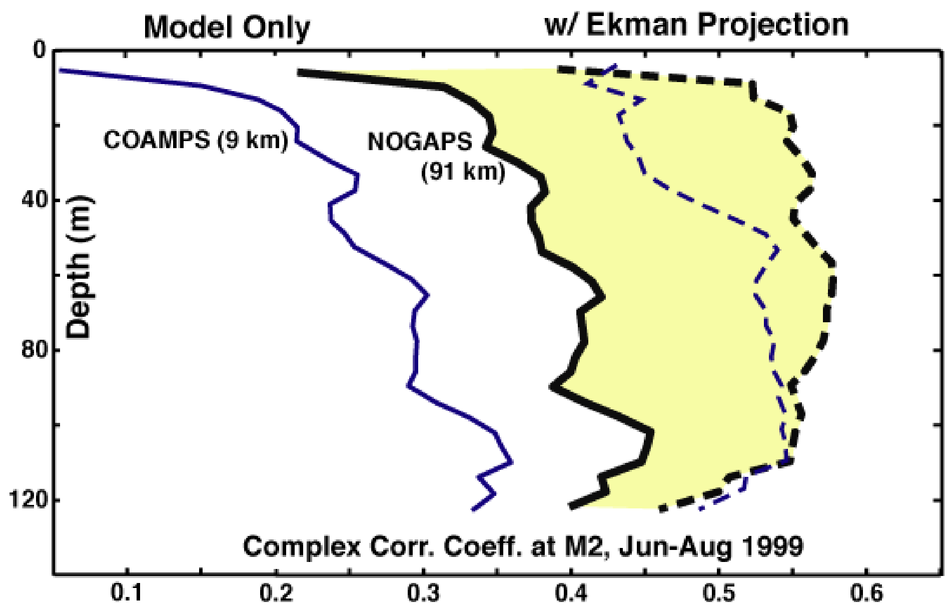

Figure 4. Amplitude of the Summer 1999 complex velocity correlation between ICON model output and observations as a function of depth from the surface to 120 m at the M2 mooring site, which is just outside the footprint of the HF radar data in Monterey Bay. Results are included for model simulations forced by low resolution (100 km; NOGAPS) and high resolution (9 km; COAMPS) winds both with and without assimilation of HF radar-derived surface currents. The assimilation significantly improves the correlations down to depths around 100 m.

IMPACT/APPLICATIONS

The likely impacts of this project include improved real-time communication, processing, and display of coastal ocean data along with improved algorithms for assimilating that data into numerical models.

TRANSITIONS

The transition opportunities are related to improved coastal nowcast and forecast systems.

RELATED PROJECTS

This project interfaces directly with the many Monterey Bay-area programs, including: HF Radar Measurements of Ocean Surface Currents and Winds (J. Vesecky; Award Number N00014-99-1-0174), the NOPP project entitled Simulations of Coastal Ocean Physics and Ecosystems (SCOPE; P.I. F. Chavez.), the Autonomous Ocean Sampling Network (AOSN) project entitled Aerial Surveys of the

Ocean and Atmosphere off Central California (Document numbers N0001401WR20317 and N0001402WR20393), NOAA's Center for Integrated Marine Technology (UC Santa Cruz), and NOAA's Sanctuary Integrated Monitoring Network (SIMoN).

PUBLICATIONS

Blencoe, David G., 2001: Impact of high resolution wind fields on coastal ocean models. M.S. Thesis, Naval Postgraduate School, Monterey, CA, September, 71 pp.

Chao, Y., Z.Li, J. Kindle, J. Paduan, and F. Chavez, 2002: A high-resolution surface vector wind product for coastal oceans: blending satellite scatterometer measurements with regional mesoscale atmospheric model simulations. Geophys. Res. Letters. In Press.

Kindle, J.C., R. Hodur, S. deRada, J. Paduan, L.K. Rosenfeld, and F. Chavez, 2002: A COAMPS™ reanalysis for the eastern Pacific: properties of the diurnal sea breeze along the central California coast. Geophys. Res. Letters, In Press.

Meadows, Lorelle A., 2002: High frequency radar measurement of friction velocity in the marine boundary layer. Ph.D. Dissertation, University of Michigan, Report No. OEL-0204, 125 pp.

Neander, D.O., 2002: Analysis of temperature variability between Davidson Seamount and Sur Ridge: the tomographic inverse problem. M.S. Thesis, Naval Postgraduate School, June, 59 pp.

Shulman, I., J.D. Paduan, C.-R. Wu, J.K. Lewis, L.K. Rosenfeld, S.R. Ramp, 2001: High frequency radar data assimilation in the Monterey Bay. Proceedings, 7th International Estuarine and Coastal Modeling Conference, St. Petersburg, Florida, 5-7 November, 434-446.

Shulman, I., C.-R. Wu, J.K. Lewis, J.D. Paduan, L.K. Rosenfeld, J.D. Kindle, S.R. Ramp, and C.A. Collins, 2002: High resolution modeling and data assimilation in the Monterey Bay area. Cont. Shelf Res., **22**, 1129-1151.

Vesecky, J. F., 2001: Multiple-Frequency HF Radar Observations of the top few Meters of the Ocean: Air-sea Interaction & Circulation. Werner Alpers Symposium: Achievements & Perspectives of Remote Sensing of the Ocean, Hamburg, Germany, Sept.–invited paper.

Vesecky, J.F., J.A. Drake, C.C. Teague, D.M. Fernandez, C. Whelan, M.A. Plume, J.D. Paduan, and P.E. Hansen, 2002: Comparison of surface current measurements by different HF radar systems with each other and with ADCP current measurements. Eos Trans. AGU, **83** (4), Ocean Sci. Meeting Suppl, Abstract OS12A-97.

Vesecky, J. F., J. Drake, M. Plume, C. C. Teague, L. Meadows, Y. Fernandez, P. Hansen, K. Davidson & J. Paduan, 2001: Multifrequency HF Radar Observations of Surface Currents: Measurements from Different Systems and Environments. Proc. IEEE OCEANS Conference, IEEE Press, Piscataway NJ.

Vesecky, J., J. Drake, C. Teague, F. Ludwig, J. Paduan & K. Davidson, 2002: Measurement of wind speed & direction using MCR radar, Proc. IEEE IGARSS Conference, IEEE Press, Piscataway NJ.